TITLE OF THE INVENTION

COLOR REGISTRATION CONTROL METHOD UTILIZING DENSITY SENSOR

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the priority of Korean Patent Application No. 2003-18771, filed on March 26, 2003, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention relates to a color registration control method, and more particularly, to a color registration control method using a density sensor.

2. Description of the Related Art

[0003] In color registration of an image forming apparatus, errors can occur due to a variety of causes, including a photo-scan error of a laser scanner unit, changes in belt steering, and changes in temperature of external environments. Color registration errors cause degradation of an image by directly causing an overlap or an isolation of images.

[0004] Among related correction methods to remove the color registration error, there are methods using a charge-coupled device (CCD), as disclosed by US. Pat. 6,424,432, and methods for correcting the number of pixel clocks by feeding a scan speed back to the pixel clock frequency with using an installed sensor capable of detecting the scan speed of a laser beam, as disclosed by JP No. 3-110512.

[0005] FIGS. 1 and 2 are a block diagram of the structure of a color registration detection apparatus and a flowchart of a color registration detection method, respectively, disclosed in the U.S. Pat. 6,424,432.

[0006] Referring to FIGS. 1 and 2, in order to detect a color registration error, first, an image processing unit 203 generates a test-pattern data for recording a halftone image, by selecting one color among cyan (C), magenta (M), yellow (Y), and black (B) in step S301. The test-pattern is recorded on a recording sheet by one of image recording heads 123 through 153, based on image data. At this time, a signal sent by the image processing unit 203 is sent to the image recording heads 123, 133, 143, and 153 after being modulated in a correction-table memory unit 204, in step S302. The test-pattern recorded on the recording sheet is reproduced by a CCD sensor 201 in step S303, and luminance information and image information are converted to density information in an arithmetic conversion unit 202 in step S304.

[0007] By storing image information of the test-pattern in a RAM 207, a CPU 206 calculates the mean value of a density value reproduced by reproducing elements for each color in step S305. After calculating the number of recording elements which have detected density values among the recording elements, that is, the number of pixels, in step S306, the CPU 206 determines whether or not the number of pixels recording the test-pattern is the same as the calculated pixel number in step S307. Accordingly, the density of pixels recorded by each recording element is detected. The CPU 206 calculates the mean value of the density values of pixels recorded by light-emitting elements detected by the method described above in step S309, and calculates the deviation of the density value of each pixel in step S310. If the number of the reproducing pixels is not the same as the number of recording pixels, magnification processing of the reproducing density pattern is performed in step S308, the mean density is calculated in step S309, and the deviation of the density value of each pixel is calculated in step S310.

[0008] A table code of a correction table is allocated to each light-emitting element in accordance with the deviation in step S311, and is stored in a table-code memory 205 corresponding to each recording element. The table code stored in the table-code memory 205 is sent to the correction-table memory unit 204, and sent to each of the recording heads 123 through 153, and thus registration correction is performed. Here, reference number 115 indicates an interface (I/F) unit which sends image information provided by an external apparatus, such as a copier, to the image processing unit.

[0009] U.S. Pat. 6,424,432, discusses developing a test-pattern for each color on a transfer belt, identifying respective intervals by using a CCD sensor, and the CPU performs correction

for the error. Accordingly, the structure of the circuit is complicated, work efficiency is low, and expensive equipment is required.

[0010] In addition, JP No. 3-110512 has drawbacks that it should keep the locations of sensors for respective colors the same, and can be applied effectively only when the scanning speed is uniform.

SUMMARY OF THE INVENTION

[0011] The invention provides a method for controlling color registration with high precision by using a density sensor with a relatively low sensitivity.

[0012] According to an aspect of the invention, there is provided a color registration control method of an image forming apparatus which comprises a first sensor and a second sensor arranged in parallel in a scanning direction on a transfer belt between a developer and a transfer unit, a comparator receiving a density signal detected by the first and second density sensors, and a control unit receiving an error signal from the comparator, the method comprising: developing a registration pattern with predetermined colors by overlapping a left-half pattern and a right-half pattern of a second pattern, and a left-half pattern and a right-half pattern of a first pattern, which are arranged symmetrically to the center, respectively, in the scanning direction; detecting density information of the left-half pattern and the right-half pattern of the registration pattern by using the first and second density sensors, and sending the detected information to the comparator; calculating a color registration error by comparing the density of the left-half pattern with the density of the right-half pattern in the comparator; and outputting from the control unit a color registration control signal in response to the error signal received by the comparator.

[0013] According to another aspect of the invention, there is provided a color registration control method of an image forming apparatus which comprises a first sensor and a second sensor arranged in parallel in a scanning direction on a transfer belt between a developer and a transfer unit, a comparator receiving a density signal detected by the first and second density sensors, and a control unit receiving an error signal from the comparator, the method comprising: arranging a left-half and a right-half of a first pattern, which are arranged symmetrically to a center, on a top side and on a bottom side, respectively, and putting a left-

half pattern and a right-half pattern of a second pattern, which are arranged, on the left-half pattern and the right-half pattern of the first pattern, respectively, in the scanning direction, thereby developing a registration pattern with predetermined colors; detecting density information of the left-half pattern and the right-half pattern of the registration pattern by using the density sensors, and sending the detected information to the comparator; calculating a color registration error by comparing the density of the left-half pattern with the density of the right-half pattern in the comparator; and outputting from the control unit a color registration control signal in response to the error signal received by the comparator.

[0014] According to another aspect of the invention, there is provided a color registration control method of an image forming apparatus which comprises a first sensor and a second sensor arranged in parallel in a scanning direction on a transfer belt between a developer and a transfer unit, a comparator receiving a density signal detected by the first and second density sensors, and a control unit receiving an error signal from the comparator, the method comprising: developing a registration pattern with predetermined colors by overlapping a left-half pattern and a right-half pattern of a second pattern, which have a predetermined bit line difference to each other in a sub-scanning direction, and a left-half pattern and a right-half pattern of a first pattern, which are arranged identically to the center, respectively, in the scanning direction; detecting density information of the left-half pattern and the right-half pattern of the registration pattern by using the first and second density sensors, and sending the detected information to the comparator; calculating a color registration error by comparing the density of the left-half pattern with the density of the right-half pattern in the comparator; and outputting from the control unit a color registration control signal in response to the error signal received by the comparator.

[0015] According to another aspect of the invention, there is provided a color registration control method of an image forming apparatus which comprises a first sensor and a second sensor arranged in parallel in a scanning direction on a transfer belt between a developer and a transfer unit, a comparator receiving a density signal detected by the first and second density sensors, and a control unit receiving an error signal from the comparator, the method comprising: arranging a left-half and a right-half of a first pattern, which are arranged identically to the center, on a top side and on a bottom side, respectively, and putting a left-half pattern and a right-half pattern of a second pattern, which have a predetermined bit line difference to each other in a sub-scanning direction, on the left-half pattern and the right-half pattern of the first

pattern, respectively, in the scanning direction, thereby developing a registration pattern with predetermined colors; detecting density information of the left-half pattern and the right-half pattern of the registration pattern by using the density sensors, and sending the detected information to the comparator; calculating a color registration error by comparing the density of the left-half pattern with the density of the right-half pattern in the comparator; and outputting from the control unit a color registration control signal in response to the error signal received by the comparator.

[0016] Preferably, in the method, in the first and second patterns, an identical bit line is developed on an identical location.

[0017] In the method, the first and second patterns comprise bit lines, whose number is a multiple of 2, and which are arranged in a sub-scanning direction. For example, in the first and second patterns, 2-, 4-, 8-, 16-, and 32-bit lines are arranged in a sub-scanning direction.

[0018] When calculating a color registration error by comparing the density of the left-half pattern with the density of the right-half pattern in the comparator, if a density difference between the left half and the right half is equal to or greater than a reference value, one is set to a first binary number, and the other is set to a second binary number, and if a density difference between the left half and the right half is less than the reference value, determination is held back, and by doing so, a density detection table is calculated.

[0019] When outputting from the control unit a color registration control signal in response to the error signal received by the comparator if an error occurs, if an error occurs, the color registration control signal is output and the method further comprises developing again the registration pattern with predetermined colors by overlapping the left-half pattern and the right-half pattern of the second pattern, and the left-half pattern and the right-half pattern of the first pattern, which are arranged symmetrically to the center, respectively, in the scanning direction.

[0020] When outputting from the control unit a color registration control signal in response to the error signal received by the comparator if an error occurs, if the error does not occur, current color registration control is finished and the method for controlling the color registration of the image forming apparatus is repeatedly performed for other color registration control.

[0021] When outputting from the control unit a color registration control signal in response to the error signal received by the comparator if an error occurs, the control unit outputs a signal controlling a laser scanning unit of a developer and a belt steering apparatus.

[0022] The present invention suggests a simple color registration pattern, and provides a method for controlling a color registration pattern, by which by using a low cost density sensor having a relatively low sensitivity, an error in a color registration pattern is detected and a registration control signal to correct this is output.

[0023] Additional aspects and/or advantages of the invention will be set forth in part in the description which follows and, in part, will be obvious from the description, or may be learned by practice of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the Office upon request and payment of the necessary fee.

[0025] The above and/or other aspects and advantages of the invention will become apparent and more readily appreciated from the following description of the embodiments taken in conjunction with the accompanying drawings in which:

FIG. 1 is a schematic diagram of a conventional structure of a color registration detection apparatus disclosed in U.S. Pat. 6,424,432;

FIG. 2 is a flowchart of a conventional color registration detection method disclosed in U.S. Pat. 6,424,432;

FIG. 3 is a schematic diagram of an image forming apparatus performing a registration control method according an embodiment of the present invention;

FIG. 4 is a flowchart of a registration control method according to an embodiment of the present invention;

FIG. 5 A is a schematic block diagram of an apparatus performing a registration control method according to an embodiment of the present invention;

FIG. 5 B is a schematic block diagram of an apparatus performing a registration control method according to an embodiment of the present invention;

FIG. 6 is a schematic diagram of a registration pattern and a density sensor when a registration control method according to an embodiment of the present invention is performed in the scanning direction;

FIG. 7 is a reference density table when the pattern shown in FIG. 6 is developed;

FIG. 8 is a diagram showing a development pattern when the pattern shown in FIG. 6 is developed and no error occurs;

FIGS. 9 A and 9 B are diagrams showing development patterns where 1- bit line errors to the left side and to the right side, respectively, in the scanning direction occurred in the reference pattern shown in FIG. 8;

FIGS. 10 A and 10 B are diagrams showing development patterns where 2-bit line errors to the left side and to the right side, respectively, in the scanning direction occurred in the reference pattern shown in FIG. 8;

FIGS. 11 A and 11 B are diagrams showing development patterns where 3-bit line errors to the left side and to the right side, respectively, in the scanning direction occurred in the reference pattern shown in FIG. 8;

FIGS. 12 A and 12 B are diagrams showing development patterns where 4-bit line errors to the left side and to the right side, respectively, in the scanning direction occurred in the reference pattern shown in FIG. 8;

FIGS. 13 A and 13 B are diagrams showing development patterns where 5-bit line errors to the left side and to the right side, respectively, in the scanning direction occurred in the reference pattern shown in FIG. 8;

FIGS. 14 A and 14 B are diagrams showing development patterns where 6-bit line errors to the left side and to the right side, respectively, in the scanning direction occurred from the reference pattern shown in FIG. 8;

FIGS. 15 A and 15 B are diagrams showing development patterns where 7-bit line errors to the left side and to the right side, respectively, in the scanning direction occurred in the reference pattern shown in FIG. 8;

FIG. 16 is a diagram showing an arrangement of the first pattern and second pattern shown in FIG. 6;

FIG. 17 is a diagram showing a development pattern of the reference pattern shown in FIG. 8;

FIG. 18 is a diagram showing a registration pattern of a registration control method according to an embodiment of the present invention when a registration error occurs in a sub-scanning direction;

FIG. 19 is a diagram showing a reference registration pattern developed by putting the first pattern on the second pattern when a registration error does not occur in a sub-scanning direction;

FIGS. 20 A and 20 B are diagrams showing development patterns where 1-bit line errors to the bottom side and to the top side, respectively, occurred in the sub-scanning direction in the reference pattern shown in FIG. 19;

FIGS. 21 A and 21 B are diagrams showing development patterns where 2-bit line errors to the bottom side and to the top side, respectively, occurred in the sub-scanning direction in the reference pattern shown in FIG. 19;

FIGS. 22 A and 22 B are diagrams showing development patterns where 3-bit line errors to the bottom side and to the top side, respectively, occurred in the sub-scanning direction in the reference pattern shown in FIG. 19;

FIGS. 23 A and 23 B are diagrams showing development patterns where 4-bit line errors to the bottom side and to the top side, respectively, occurred in the sub-scanning direction in the reference pattern shown in FIG. 19;

FIGS. 24 A and 24 B are diagrams showing development patterns where 5-bit line errors to the bottom side and to the top side, respectively, occurred in the sub-scanning direction in the reference pattern shown in FIG. 19;

FIGS. 25 A and 25 B are diagrams showing development patterns where 6-bit line errors to the bottom side and to the top side, respectively, occurred in the sub-scanning direction in the reference pattern shown in FIG. 19;

FIGS. 26 A and 26 B are diagrams showing development patterns where 7-bit line errors to the bottom side and to the top side, respectively, occurred in the sub-scanning direction in the reference pattern shown in FIG. 19; and

FIG. 27 is a reference density table when the pattern shown in FIG. 18 is developed.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0026] Reference will now be made in detail to the embodiments of the present invention, examples of which are illustrated in the accompanying drawings, wherein like reference

numerals refer to the like elements throughout. The embodiments are described below to explain the present invention by referring to the figures.

[0027] FIG. 3 is a schematic diagram of an image forming apparatus where a color registration control method according to an embodiment of the present invention is performed, and a color registration pattern.

[0028] Referring to FIG. 3, the image forming apparatus comprises an electric charger 23 which raises the electric potential of an intermediate transfer belt 21 to an exposure electric potential, a laser scanning unit (LSU) 25 which forms an electrostatic latent image on a photosensitive drum 27, a development roller 29 which transfers a predetermined color development liquid to develop the electrostatic latent image on the photosensitive drum 27, a first transfer roller 26 which pressures the intermediate transfer belt 21 that is held between the first transfer roller 26 and the photosensitive drum 27 and rotates to transfer the developed image on the photoconductor to the intermediate transfer belt 21, and second rollers 28a and 28b which transfer the developed image to a sheet. Here, reference numbers 22 and 24 indicate a first and a second rotation rollers rotating the intermediate transfer belt 21.

[0029] A first and a second sensors (D1, D2) are located on the intermediate transfer belt 21 between the development roller 29, as a developer of the image forming apparatus, and the second transfer rollers 28a and 28b, as transfer units, and detect the density of the developed registration patterns (A, B, C, D, E). Here, the first and the second density sensors (D1, D2) may be replaced by one density sensor.

[0030] When color registration patterns (A, B, C, D, E) are detected by one density sensor, each of the color registration patterns (A, B, C, D, E) are divided into a left side and a right side of the center, and then arranged in a sub-scanning direction such that a total of 5 patterns, including 2-, 4-, 8-, 16-, and 32-bit lines, are arranged. Here, the color registration pattern is not limited to the pattern shown in FIG. 3 and according to the registration error range desired to be detected, a variety of patterns, numbering 12 or more patterns, can be formed in a variety of ways. However, since in the color registration control method according to an embodiment of the invention, the mechanical error range of the image forming apparatus is expected to be a maximum 32-bit line in the registration error, the color registration pattern is formed with the five bit line patterns as shown.

[0031] FIG. 4 is a flowchart of a registration control method in accordance with an embodiment of the present invention.

[0032] Referring to FIG. 4, in order to perform the color registration control method in accordance with an embodiment of the invention, first, a predetermined test pattern is developed in step 11, and density information comparing the left-half density and right-half density of the test pattern is detected in step 12. Here, the predetermined test pattern may comprise, as shown in FIG. 6, a first pattern where the left-half pattern and the right-half pattern are arranged symmetrically to the center (O), and a second pattern where the left-half pattern and the right-half pattern are identically arranged. Also, a registration pattern where the left and the right patterns of the first and the second patterns are arranged on the top and bottom, respectively, as shown in FIG. 16, may be formed.

[0033] FIG. 6 is a schematic diagram of a registration pattern for performing a registration control method according to a preferred embodiment of the present invention when a registration error occurs in the X-axis direction, that is, in the scanning direction.

[0034] Referring to FIG. 6, the first pattern comprises P11 pattern where 2-bit lines (1, 0) are arranged in the left-half pattern and the right-half pattern that are symmetrical to the center (O), P12 pattern where 4-bit lines (1, 1, 0, 0) are arranged in the left-half pattern and the right-half pattern that are symmetrical to the center (O), P13 pattern where 8-bit lines (1, 1, 1, 1, 0, 0, 0, 0) are arranged in the left-half pattern and the right-half pattern that are symmetrical to the center (O), P14 pattern where 16-bit lines (1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0) are arranged in the left-half pattern and the right-half pattern that are symmetrical to the center (O), and P15 pattern where 32-bit lines (1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0) are arranged in the left-half pattern and the right-half pattern that are symmetrical to the center (O). One indicates a bit line to be developed, and zero indicates a bit line not to be developed.

[0035] The second pattern comprises 2-bit lines (P21 pattern), 4-bit lines (P22 pattern), 8-bit lines (P23 pattern), 16-bit lines (P24 pattern), and 32-bit lines (P25 pattern), but unlike the first pattern, the left-half pattern and the right-half pattern of the second pattern are not symmetrical to the center (O), but identical to each other and bit lines are identically arranged in the left-half pattern and the right-half pattern.

[0036] In order to detect a color registration error, in operation 11, the left-half pattern of the first pattern is put on the left-half of the second pattern and the right-half pattern of the first pattern is put on the right-half of the second pattern, and then developed. The pattern is developed after the putting is detected by the first and second sensors 31 and 32, as shown in FIG. 6. When there is no registration error, the registration pattern where the first pattern is put on the second pattern is shown as FIG. 8. That is, the registration pattern shown in FIG. 8 becomes a reference registration pattern when the first and second patterns shown in FIG. 6 are developed.

[0037] In the reference registration pattern, P11 pattern of the first pattern and P21 pattern of the second pattern are put together and developed as pattern A, P12 pattern and P22 pattern are put together and developed as pattern B, P13 pattern and P23 pattern are put together and developed as pattern C, P14 pattern and P24 pattern are put together and developed as pattern D, and P15 pattern and P25 pattern are put together and developed as pattern E.

[0038] Referring back to FIG. 4, in operation 12, the density error of the left-half pattern and the right-half pattern is detected. If the density of the left-half pattern is higher than that of the right-half pattern, value 0 is allocated, if the density of the left-half pattern is lower than that of the right-half pattern, value 1 is allocated, and if there is no difference between the densities of the left-half pattern and the right-half pattern, determination is held back (Δ), and by doing so, the detected density table can be obtained in operation 13 of FIG. 4.

[0039] Since the registration pattern as shown in FIG. 8 has no error, it corresponds to error (0) in the first row of FIG. 7. According to the binary number allocation rule described above, value 0 is allocated to patterns A, B, C, and D because the density of the left-half pattern is higher than that of the right-half pattern. In pattern E, the densities of the left-half pattern and the right-half pattern are similar, and determination is held back and pattern E is marked by Δ.

[0040] However, when an error occurs, as shown in FIGS. 9 A through 15 B, the development pattern of the left-half pattern and right-half pattern varies, and according to this, density information of the left-half pattern and the right-half pattern detected by the first and second density sensors also vary.

[0041] FIGS. 9 A and 9 B show registration patterns developed when 1- bit line errors to the left side and to the right side, respectively, in the scanning direction occurred.

[0042] Referring to FIG. 9 A, value 1 is allocated for pattern A where the density of the left-half pattern is detected lower than that of the right-half pattern, Δ is allocated for pattern B where the densities of the left-half pattern and right-half pattern are detected similar to each other, and 0 is allocated for patterns C, D, and E where the density of the left-half pattern is detected higher than that of the right-half pattern. By doing so, a detected density table (1, Δ, 0, 0, 0) corresponding to error (-1) of FIG. 7 is obtained.

[0043] Accordingly, if by running the image forming apparatus, the pattern as shown in FIG. 9A is developed, and the values output from the first and second density sensors are obtained as A(1), B(Δ), C(0), D(0), E(0), it can be found, from the reference density table of FIG. 7, that error (-1) occurs.

[0044] Referring to FIG. 9 B, 1 is allocated for pattern A where the density of the left-half pattern is lower than that of the right-half pattern, 1 is allocated for pattern E in the same manner, Δ is allocated for pattern B where the densities of the left-half pattern and the right-half pattern are similar, and 0 is allocated to patterns C and D where the density of the left-half pattern is higher than that of the right-half pattern. It can be found that the obtained detected density table (1, Δ, 0, 0, 1) corresponds to error (1) of FIG. 7.

[0045] FIGS. 10 A and 10 B are diagrams showing registration patterns where the second pattern shows 2-bit line errors to the left side and to the right side, respectively, from the first pattern.

[0046] Referring to FIG. 10 A, 0 is allocated to pattern A, 1 is allocated to pattern B, Δ is allocated to pattern C, 0 is allocated to pattern D, and 0 is allocated to pattern E. It can be found that this detected density table (0, 1, Δ, 0, 0) corresponds to error (-2) of FIG. 7.

[0047] Referring to FIG. 10 B, 0 is allocated to pattern A, 1 is allocated to pattern B, Δ is allocated to pattern C, 0 is allocated to pattern D, and 1 is allocated to pattern E. It can be found that this density table corresponds to error (2) of FIG. 7.

[0048] FIGS. 11 A and 11 B are diagrams showing registration patterns where the second pattern shows 3-bit line errors to the left side and to the right side, respectively, from the first pattern. Referring to FIG. 11 A, according to the same rule, a density table of A(1), B(Δ), C(1), D(0), E(0) can be obtained, and it can be found that this density table corresponds to error (-3)

of FIG. 7. Referring to FIG. 11 B, a density table of A(1), B(Δ), C(1), D(0), E(1) can be obtained, and it can be found that this density table corresponds to error (3) of FIG. 7.

[0049] FIGS. 12 A and 12 B are diagrams showing registration patterns where the second pattern shows 4-bit line errors to the left side and to the right side, respectively, from the first pattern. Referring to FIG. 12 A, a density table of A(0), B(0), C(1), D(Δ), E(0) can be obtained, and it can be found that this density table corresponds to error (-4) of FIG. 7. Referring to FIG. 12 B, a density table of A(0), B(0), C(1), D(Δ), E(1) can be obtained, and it can be found that this density table corresponds to error (4) of FIG. 7.

[0050] FIGS. 13 A and 13 B are diagrams showing registration patterns where the second pattern shows 5-bit line errors to the left side and to the right side, respectively, from the first pattern. Referring to FIG. 13 A, a density table of A(1), B(Δ), C(1), D(1), E(0) can be obtained, and it can be found that this density table corresponds to error (-5) of FIG. 7. Referring to FIG. 13 B, a density table of A(1), B(Δ), C(1), D(1), E(1) can be obtained, and it can be found that this density table corresponds to error (5) of FIG. 7.

[0051] FIGS. 14 A and 14 B are diagrams showing registration patterns where the second pattern shows 6-bit line errors to the left side and to the right side, respectively, from the first pattern. Referring to FIG. 14 A, a density table of A(0), B(1), C(Δ), D(1), E(0) can be obtained, and it can be found that this density table corresponds to error (-6) of FIG. 7. Referring to FIG. 14 B, a density table of A(0), B(1), C(Δ), D(1), E(1) can be obtained, and it can be found that this density table corresponds to error (6) of FIG. 7.

[0052] FIGS. 15 A and 15 B are diagrams showing registration patterns where the second pattern shows 7-bit line errors to the left side and to the right side, respectively, from the first pattern. Referring to FIG. 15 A, a density table of A(1), B(Δ), C(0), D(1), E(0) can be obtained, and it can be found that this density table corresponds to error (-7) of FIG. 7. Referring to FIG. 15 B, a density table of A(1), B(Δ), C(0), D(1), E(1) can be obtained, and it can be found that this density table corresponds to error (7) of FIG. 7.

[0053] When 1 through 7-bit line errors to the left side and to the right side occur in the reference registration pattern shown in FIG. 8, the reference density table shown in FIG. 7 can be obtained from the development patterns as shown in FIGS. 9 A through 15 B. After storing this reference density table in the CPU, a registration pattern is developed in the image forming

apparatus and by comparing densities of the left-half pattern and the right-half pattern, a detected density table is obtained. Then by comparing the reference density table in operation 14 of FIG. 4, whether a predetermined registration error occurred can be detected in operation 15 of FIG. 4.

[0054] If the density for each bit is detected at once and there is an err or, in order to correct this error, the control unit outputs a signal for registration control corresponding to relative coordinates so that registration can be controlled in operation 16 of FIG. 4. After controlling registration, in order to check that the modified registration is accurate, a test pattern is developed in operation 11 and density information of the left and right patterns is detected in the operation 12. Based on the detected density information, a detected density table is calculated in the operation 13 and the detected density table and the reference density table are compared in the operation 14. The procedure for detecting information on the registration is the same as described above.

[0055] If this registration control method is performed and no error occurs, the corresponding color registration procedure is finished and the next color registration control can be started.

[0056] However, if the development pattern as shown in FIG. 8 is output from the beginning, no registration error occurs, therefore, the procedure is finished and printing is continuously performed to develop the test pattern of another color registration.

[0057] FIG. 5 A is a schematic block diagram of an apparatus for detecting the registration pattern, which is developed after the first and second patterns as shown in FIG. 6 are put together, by using the first and second density sensors 31 and 32.

[0058] Referring to FIG. 5 A, the first density signal S1 of the left-half pattern detected by the first density sensor 31 is amplified by a first amplifier 33a, converted by a first A/D converter 34a from an analog signal to a digital signal, and then input to a comparator 35 of the CPU. The second density signal S2 of the right-half pattern detected by the second density sensor 32 is amplified by a second amplifier 33b, converted by a second A/D converter 34b from an analog signal to a digital signal, and then input to the comparator 35 of the CPU. By comparing the first density signal S1 and the second density signal S2, the comparator 35 detects a density table according to the rule described above, calculates a corresponding error from the reference density table as shown in FIG. 7, and outputs a signal corresponding to the detected error, to

the control unit 36. The control unit 36 outputs a signal capable of controlling registration of the image forming apparatus, for example, a control signal for the LSU, or a belt steering signal.

[0059] FIG. 5 B is a schematic block diagram of an apparatus which has only one density sensor and controls registration. When only one density sensor is installed, as shown in FIG. 16, each of the first patterns P11, P12, P13, P14, and P15 and the second patterns P21, P22, P23, P24, and P25 is divided into a left-half pattern and a right-half pattern from the center, and arranged on the top and bottom, respectively, in the sub-scanning direction.

[0060] Also in this case, the left-half (top-side) pattern of the first patterns P11, P12, P13, P14, and P15 is put on the left-half (top-side) pattern of the second patterns P21, P22, P23, P24, and P25 and then developed, and the right-half (bottom-side) pattern of the first patterns P11, P12, P13, P14, and P15 is put on the right-half (bottom-side) pattern of the second patterns P21, P22, P23, P24, and P25 and then developed. The reference registration developed has a shape, in which the left-half pattern of the reference registration pattern of FIG. 8 is put on the top side and the right-half pattern is put on the bottom side, as the registration patterns A, B, C, D, and E shown in FIG. 17.

[0061] Referring again to FIG. 5 B, in the registration control method according to a preferred embodiment of the present invention, the first signal (S1) detected in the top-side pattern and the second signal (S2) detected in the bottom-side pattern by using the density sensor 41 are sent to the amplifier 43, amplified in the amplifier 43, then sent to the A/D converter 44 and converted into a digital signal. The converted signals are input to the comparator 45, and the comparator 45 calculates a density table by comparing the first signal (S1) and the second signal (S2), finds a registration error from the reference density table, and outputs information on a corresponding error, to the control unit 46. By doing so, registration is controlled.

[0062] FIG. 18 is a diagram showing a registration pattern of a registration control method according to an embodiment of the invention when a registration error occurs in the Y-axis direction, that is, in the sub-scanning direction.

[0063] Referring to FIG. 18, the first pattern of the registration pattern, where the left-half patterns and the right-half patterns are identically arranged, comprises Q11 pattern where 2-bit lines are arranged, Q12 pattern where 4-bit lines are arranged, Q13 pattern where 8-bit lines are arranged, Q14 pattern where 16-bit lines are arranged, and Q15 pattern where 32-bit lines

are arranged. Unlike the first pattern, the second pattern comprises Q12 pattern where the left-half pattern and the right-half pattern have a 2-bit line difference in the sub-scanning direction, Q22 pattern where the left-half pattern and the right-half pattern have a 4-bit line difference in the sub-scanning direction, Q23 pattern where the left-half pattern and the right-half pattern have an 8-bit line difference in the sub-scanning direction, Q24 pattern where the left-half pattern and the right-half pattern have a 16-bit line difference in the sub-scanning direction, and Q25 pattern where the left-half pattern and the right-half pattern have a 32-bit line difference in the sub-scanning direction.

[0064] FIG. 19 is a diagram showing a reference registration pattern developed by putting the first pattern on the second pattern when a registration error does not occur in a sub-scanning direction. Referring to FIG. 19, if the density of the left-half pattern is higher than that of the right-half pattern, the pattern is set to 0, if the density of the left-half pattern is lower than that of the right-half pattern, the pattern is set to 1, and if the densities of the left-half pattern and the right-half pattern are similar, determination on the pattern is held back. When this density setting rule is applied, the detected density table of the reference registration pattern is given as A(1), B(1), C(1), D(1), E(1).

[0065] FIG. 20 A is a diagram showing a registration pattern when a 1-bit line registration error to the bottom side of the second pattern from the first pattern occurs in the sub-scanning direction. Referring to FIG. 20 A, the detected density table is obtained as A(0), B(Δ), C(1), D(1), E(0).

[0066] FIG. 20 B is a diagram showing a registration pattern when a 1-bit line registration error to the top side of the second pattern from the first pattern occurs in the sub-scanning direction. Referring to FIG. 20 B, the detected density table is obtained as A(0), B(Δ), C(1), D(1), E(1).

[0067] FIG. 21 A is a diagram showing a registration pattern when a 2-bit line registration error to the bottom side of the second pattern from the first pattern occurs in the sub-scanning direction. Referring to FIG. 21 A, the detected density table is obtained as A(1), B(0), C(Δ), D(1), E(0).

[0068] FIG. 21 B is a diagram showing a registration pattern when a 2-bit line registration error to the bottom side of the second pattern from the first pattern occurs in the sub-scanning

direction. Referring to FIG. 21 B, the detected density table is obtained as A(1), B(0), C(Δ), D(1), E(1).

[0069] FIG. 22 A is a diagram showing a registration pattern when a 3-bit line registration error to the bottom side of the second pattern from the first pattern occurs in the sub-scanning direction. FIG. 22 A is a diagram showing a registration pattern when a 3-bit line registration error to the top side of the second pattern from the first pattern occurs in the sub-scanning direction. Referring to FIG. 22 A, it is shown that the detected density table is obtained as A(0), B(Δ), C(0), D(1), E(0). Referring to FIG. 22 B, it is shown that the detected density table is obtained as A(0), B(Δ), C(0), D(1), E(1).

[0070] FIG. 23 A is a diagram showing a registration pattern when a 4-bit line registration error to the bottom side of the second pattern from the first pattern occurs in the sub-scanning direction. FIG. 23 B is a diagram showing a registration pattern when a 4-bit line registration error to the top side of the second pattern from the first pattern occurs in the sub-scanning direction. Referring to FIG. 23 A, it is shown that the detected density table is obtained as A(1), B(1), C(0), D(Δ), E(0). Referring to FIG. 23 B, it is shown that the detected density table is obtained as A(1), B(1), C(0), D(Δ), E(1).

[0071] FIG. 24 A is a diagram showing a registration pattern when a 5-bit line registration error to the bottom side of the second pattern from the first pattern occurs in the sub-scanning direction. FIG. 24 B is a diagram showing a registration pattern when a 5-bit line registration error to the top side of the second pattern from the first pattern occurs in the sub-scanning direction. Referring to FIG. 24 A, it is shown that the detected density table is obtained as A(0), B(Δ), C(0), D(Δ), E(0). Referring to FIG. 24 B, it is shown that the detected density table is obtained as A(0), B(Δ), C(0), D(Δ), E(1).

[0072] FIG. 25 A is a diagram showing a registration pattern when a 6-bit line registration error to the bottom side of the second pattern from the first pattern occurs in the sub-scanning direction. FIG. 25 B is a diagram showing a registration pattern when a 6-bit line registration error to the top side of the second pattern from the first pattern occurs in the sub-scanning direction. Referring to FIG. 25 A, it is shown that the detected density table is obtained as A(1), B(0), C(Δ), D(0), E(0). Referring to FIG. 25 B, it is shown that the detected density table is obtained as A(1), B(0), C(Δ), D(0), E(1).

[0073] FIG. 26 A is a diagram showing a registration pattern when a 7-bit line registration error to the bottom side of the second pattern from the first pattern occurs in the sub-scanning direction. FIG. 26 B is a diagram showing a registration pattern when a 7-bit line registration error to the top side of the second pattern from the first pattern occurs in the sub-scanning direction. Referring to FIG. 26 A, it is shown that the detected density table is obtained as A(0), B(Δ), C(1), D(0), E(0). Referring to FIG. 26 B, it is shown that the detected density table is obtained as A(0), B(Δ), C(1), D(0), E(1).

[0074] These show the values that correspond to the reference density table of FIG. 27. When printing is performed by the image forming apparatus, by comparing the detected density table, which is calculated by comparing the densities of the left-half pattern and the right-half pattern of the developed registration pattern, with the reference density table, it can be found how many bit lines of a registration error has occurred.

[0075] When the registration pattern, in which the left-half pattern and the right-half pattern of each of the first pattern and the second pattern is arranged on the top side and on the bottom side, respectively, is developed, the density detection table described above can be identically calculated by installing one density sensor.

[0076] The invention forms the first pattern, in which the left-half pattern and the right-half pattern are symmetrically arranged, and the second pattern, in which the left-half pattern and the right-half pattern are identically arranged, such that the registration error in the X-axis direction can be detected. Also, the invention forms the first pattern, in which the left-half pattern and the right-half pattern are identically arranged, and the second pattern, in which the left-half pattern and the right-half pattern are arranged with a predetermined bit line difference in the sub-scanning direction, such that the registration error in the sub-scanning direction can be detected. In the registration pattern, color registration can be controlled by removing the registration error with high precision, by using a simple circuit structure with a plurality of density sensors and a simple procedure according to the formed patterns.

[0077] Although a few embodiments of the present invention have been shown and described, it would be appreciated by those skilled in the art that changes may be made in this embodiment without departing from the principles and spirit of the invention, the scope of which is defined in the claims and their equivalents.